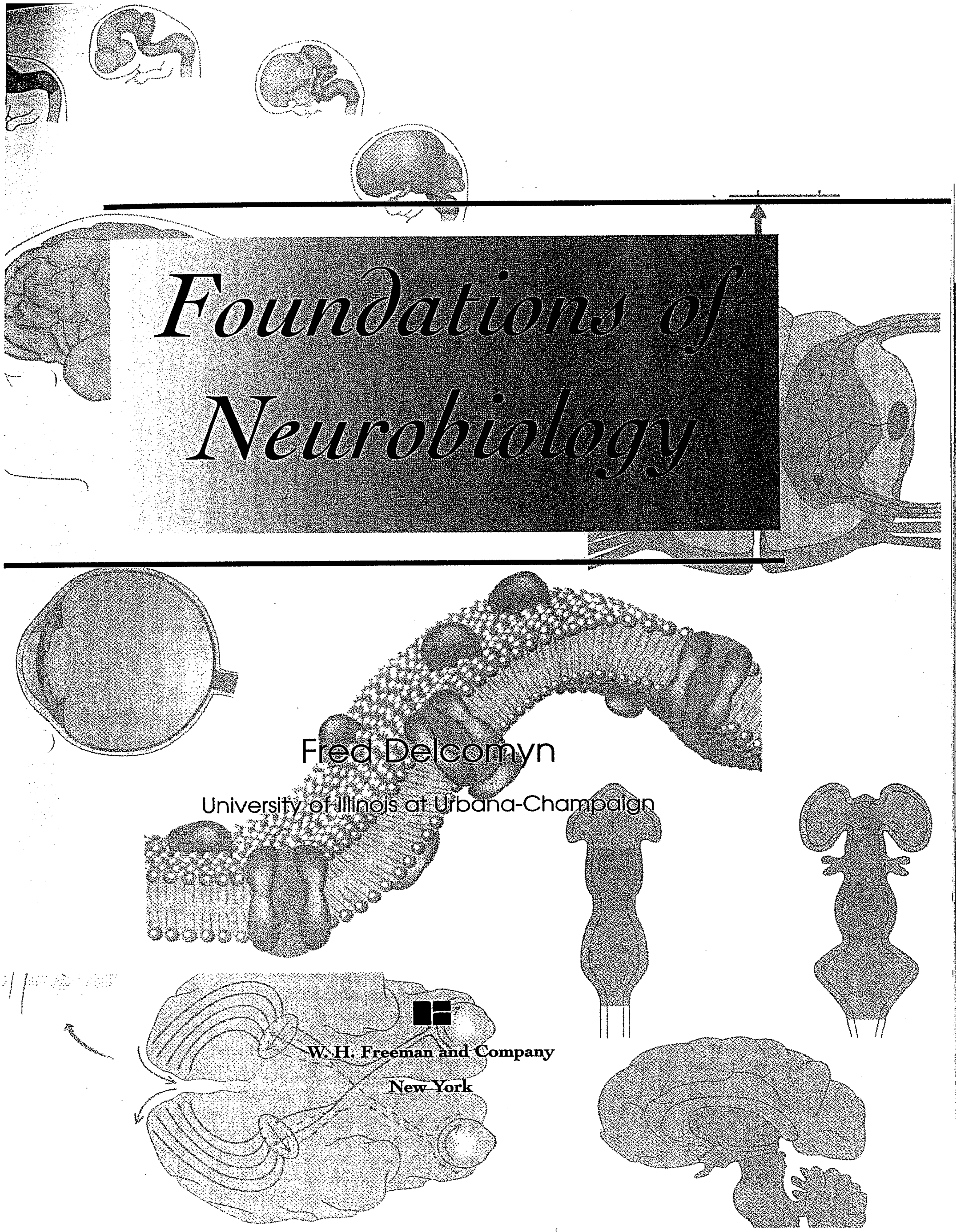
**ATTACHMENT 3**



# *Foundations of Neurobiology*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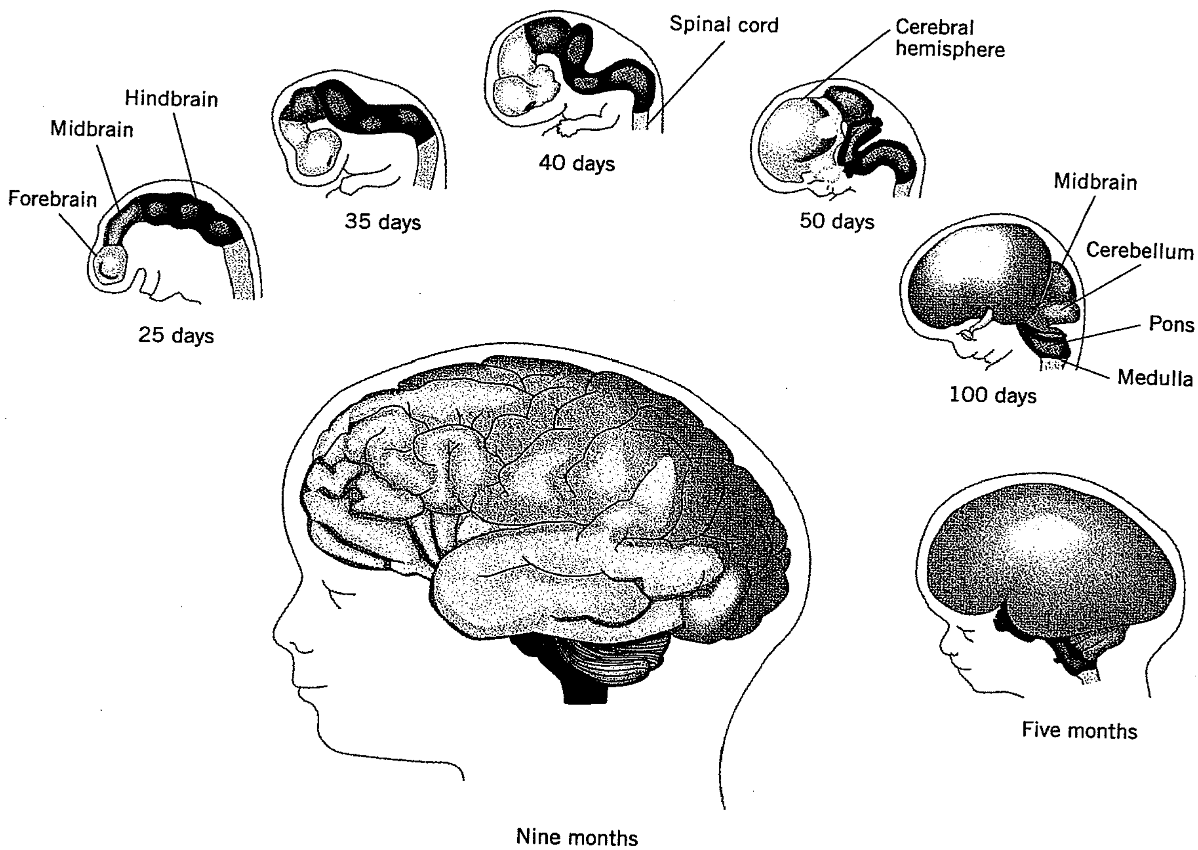


**FIGURE 3-12.** The development of the human brain. As the neural tube differentiates, it folds and bends on itself. The main lobes of the brain develop last.

the interior of the brain, the diencephalon and its two main constituent structures, the hypothalamus and the thalamus, remain intact, perched atop the midbrain.

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Rapid growth of specific regions of the embryonic brain causes formation of the cerebellum on top of the hindbrain and of the cerebral hemispheres, which cover virtually all the brain structures beneath it.

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## The Lower Brain

When you look at the nervous system in a vertebrate embryo and at the brain of a relatively simple vertebrate like a fish, it is easy to see the fundamentally linear arrangement of the spinal cord and the brain. Even in the highly developed mammalian brain, the medulla, the pons, and the midbrain are arranged in a row, one after the other (Figure 3-13). By analogy with the straight stem of a plant with a flower perched on top, these parts of the brain can be thought of as the stem that supports the flower represented by the cerebral hemispheres. The analogy is particularly apt because these linearly arranged parts of the brain are collectively referred to as the **brain stem**. The cerebellum, because it sits perched above the pons rather than being in line with the other parts of the hindbrain, is not included in the brain stem. Based on its embryological origin, however, it is part of the hindbrain. The parts of the brain stem all contribute to the regulation of basic bodily functions such as respiration and heartbeat.

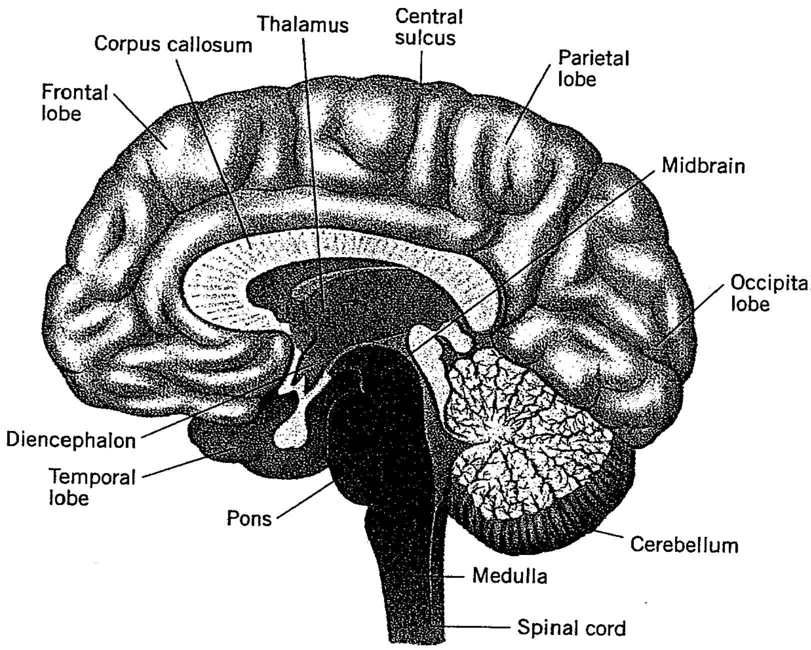


**FIGURE 3-13.** Section through the middle of the human brain, showing the medulla, pons, and midbrain (collectively the brain stem) in relation to some of the other main structures of the human brain. Some of the labeled parts are discussed in later sections of this chapter.

## The Medulla and the Pons

Two components of the hindbrain are part of the brain stem. The medulla arises directly from the spinal cord, and looks somewhat like an enlargement of the cord. Joined to the anterior end of the medulla is the pons, a bulbous part of the brain stem that is distinctive for the fluting of its external surface (see Figure 3-9). From an evolutionary point of view, these parts of the hindbrain constitute the oldest part of the brain. In line with its primitive origins, many parts of the hindbrain control what you might think of as the "primitive" functions in the animal's body, those that are fundamental to life and not under conscious control. Both the medulla and the pons contain important nuclei, control centers containing cell bodies and dendrites of neurons that help to control vital functions like breathing, heart rate, and blood pressure, and that are responsible for initiating the reflexive actions of coughing, gagging, and vomiting.

Some of the medullary and pontine nuclei are associated with **cranial nerves.** These nuclei contain the cell bodies of motor neurons that leave the brain via some of the cranial nerves. Like spinal nerves, cranial nerves serve as the communication links between the CNS, the brain in this case, and the rest of the body. However, whereas spinal nerves are all organized in the same pattern (dorsal roots being sensory, ventral roots being largely motor), not all cranial nerves are the same. Some are efferent, carrying motor information to muscles and glands; some are afferent, bringing sensory information into the brain; and some are mixed, carrying both efferent and afferent fibers. Not all cranial nerves connect with the medulla and pons; some also connect to the mesencephalon and the forebrain. The locations of the 12 pairs of cranial nerves are shown in Figure 3-14, and their functions and the type of information they carry are listed in Table 3-3.

In addition to housing important control nuclei, the brain stem is also a major pathway for communication within the CNS. Some of the nerve tracts found there connect one nucleus in the brain stem to another, some connect nuclei in the brain stem to the

**TABLE 3-3. The Cranial Nerves**

| Nerve | Function | Origin of Motor Nerves | Destination of Sensory Nerves |
|---|---|---|---|
| I Olfactory | Sensory: olfactory input | | Olfactory bulb |
| II Optic | Sensory: visual input | | Lateral geniculate nucleus (thalamus) |
| III Oculomotor | Motor: controls most eye muscles | Mesencephalon | |
| IV Trochlear | Motor: controls superior oblique eye muscles | Mesencephalon | |
| V Trigeminal | Mixed: carries sensory input from the face; controls muscles that move the jaw | Pons | Mesencephalon, pons, and medulla |
| VI Abducens | Motor: controls external rectus eye muscles | Pons | |
| VII Facial | Mixed: carries sensory input from tongue and palate; controls muscles of the face | Pons | Pons and medulla |
| VIII Vestibulocochlear (vestibular, cochlear) | Sensory: carries auditory input and input concerning balance | | Pons and medulla |
| IX Glossopharyngeal | Mixed: carries sensory input from the tongue and throat; controls throat muscles | Medulla | Pons and medulla |
| X Vagus | Mixed (autonomic): carries sensory input from the heart, lungs, and viscera; controls movements of the heart, lungs, and viscera | Medulla | Pons and medulla |
| XI Accessory | Motor: controls neck muscles | Medulla | |
| XII Hypoglossal | Motor: controls tongue and neck muscles | Medulla | |

spinal cord and to nuclei in the rest of the brain, and some go right through the brain stem, connecting spinal centers to nuclei in the midbrain and forebrain. Tracts that interconnect nuclei within the brain stem are important for the proper execution of many vital reflexes.

Among the most prominent of the tracts that course through the brain stem are the two ventrally located **pyramidal tracts.** These tracts, which derive their name from the pyramid-shaped part of the medulla through which they travel (Figure 3-15), carry axons that convey motor information from the motor centers in the forebrain to the motor centers in the spinal cord. Tracts of this type, which carry information from the cortex to the spinal cord, are called **corticospinal tracts.** Tracts conveying information in the opposite direction are called **spinocortical tracts.**

Distributed throughout the brain stem is a loose network of neurons called the **reticular formation,** or **reticular activating system.** Neurons of this network form a number of biochemically and morphologically distinct groups within the brain stem, groups that communicate extensively with one another as well as with other parts of the brain. Researchers have identified four important

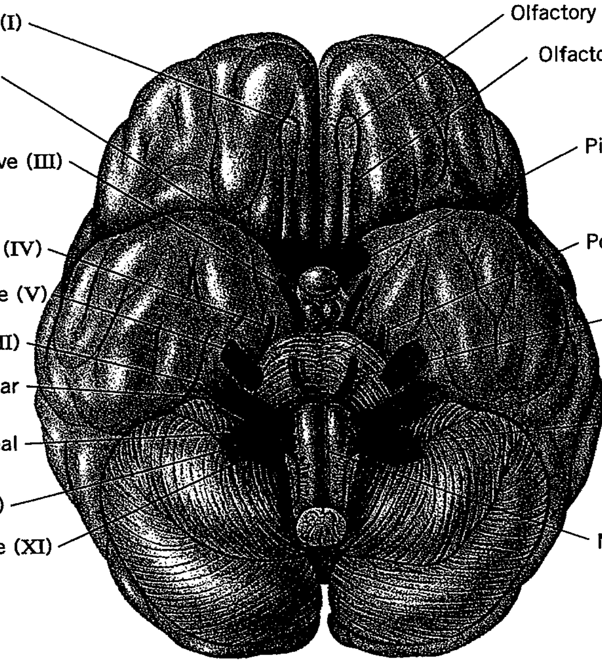


**FIGURE 3-14.** The cranial nerves of the human brain, shown in ventral view. Several nerves have origins or destinations in more than one part of the brain.

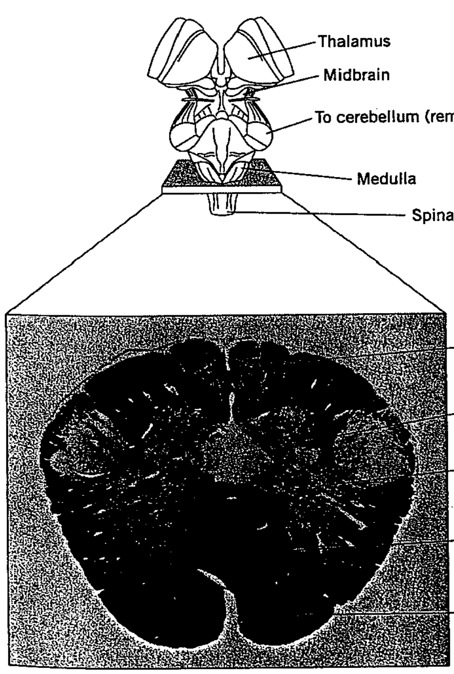


**FIGURE 3-15.** Photomicrograph of a section through the human medulla. The drawing, a dorsal view of the brain stem, shows the level of the section in a dorsal view.

functions of the system. These are (1) to modulate the sensation of pain; (2) to modulate certain postural reflexes and muscle tone; (3) to help control breathing and heartbeat; and (4) to regulate the level of brain arousal and, in humans, consciousness. The last function is that with which the reticular formation is the most closely associated. For example, the **raphe nuclei** that lie along the midline of the medulla, pons, and midbrain are especially important in maintaining wakefulness (Figure 3-16). Damage to them can result in permanent coma.

All sensory input that enters the brain via the medulla is also sent to neurons of the reticular formation. These may monitor sensory input for importance, and alert higher brain centers when critical input is detected. It has been suggested that the reticular formation is able to do this in part because it receives input from the cortex and uses that input as the basis for its decisions.